

EMCal Optical Sensors, Readout Electronics, DAQ and Trigger

WBS 1.07/1.08

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EMCal Internal Review
20-Aug-2015

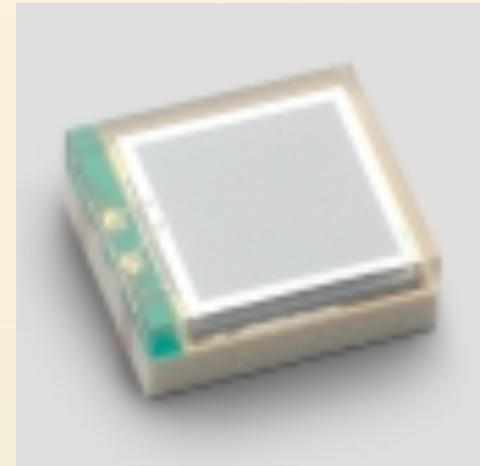


EMCal Electronics Design Concept

- Minimize custom ASICs -> off the shelf components
- Same optical sensor for EMCal and HCal
- Similar readout for both EMCal and HCal
 - Continuous digitization of wave forms
 - Trigger primitives for Level-1 trigger
 - High DAQ rate, ~15KHz
- Minimize On-Detector power/heat load
- Use PHENIX DAQ
 - DCM-II
 - Event Builder
 - Data Logging
 - Monitoring
- Common biasing and low voltage systems

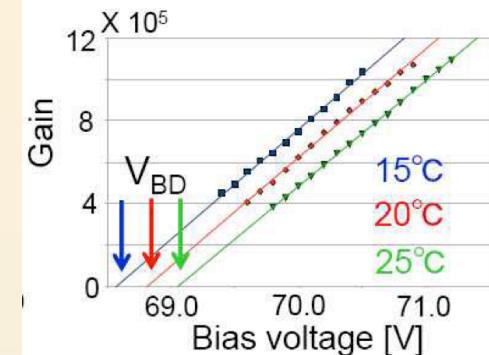
Optical Sensors Reference Design

- Silicon Photomultiplier, SiPM or MPPC
- High gain, $\sim 10^5$
- Dynamic range set by number of microcells
- Immune to magnetic fields
- Relatively inexpensive, $\sim \$10$ in large quantities
- Reference device: Hamamatsu S12572
 - $15 \mu\text{m}^2$ pixel size
 - 40K microcells
 - $\sim 25\%$ Photon Detection Efficiency (PDE)
 - Spectral response: 320-900nm
- Potential concerns
 - Temperature dependence
 - Radiation effects

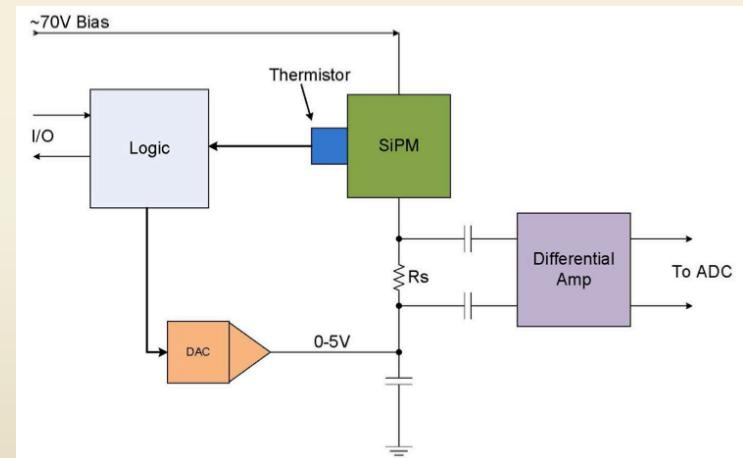


Temperature Dependence

- SiPM gain is set by the overvoltage applied to the device:
 - $V_{op} = V_{br} + V_{ov}$
- Temperature dependence:
 - $\sim 10\%/\text{°C}$
- Local thermistor to monitor temperature
- Positive feedback loop will be used to adjust the voltage to compensate for temperature fluctuations

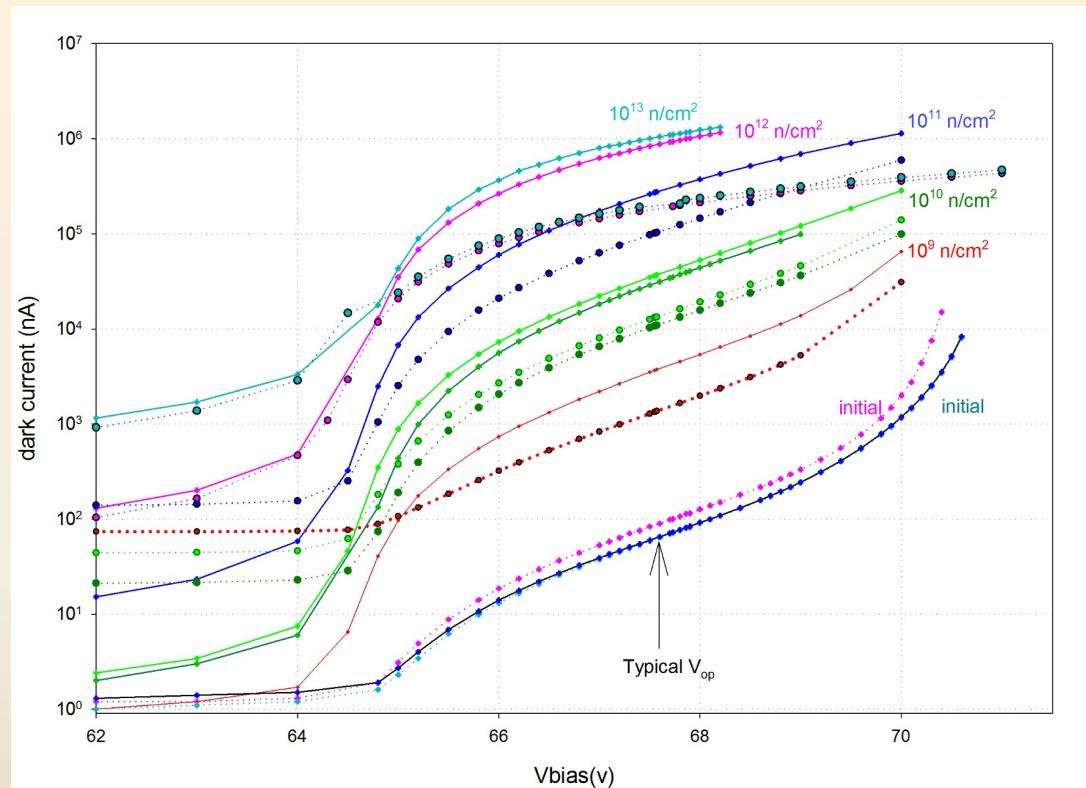


Minamino, Akihiro et al.
"T2K experiment: Neutrino Detectors"



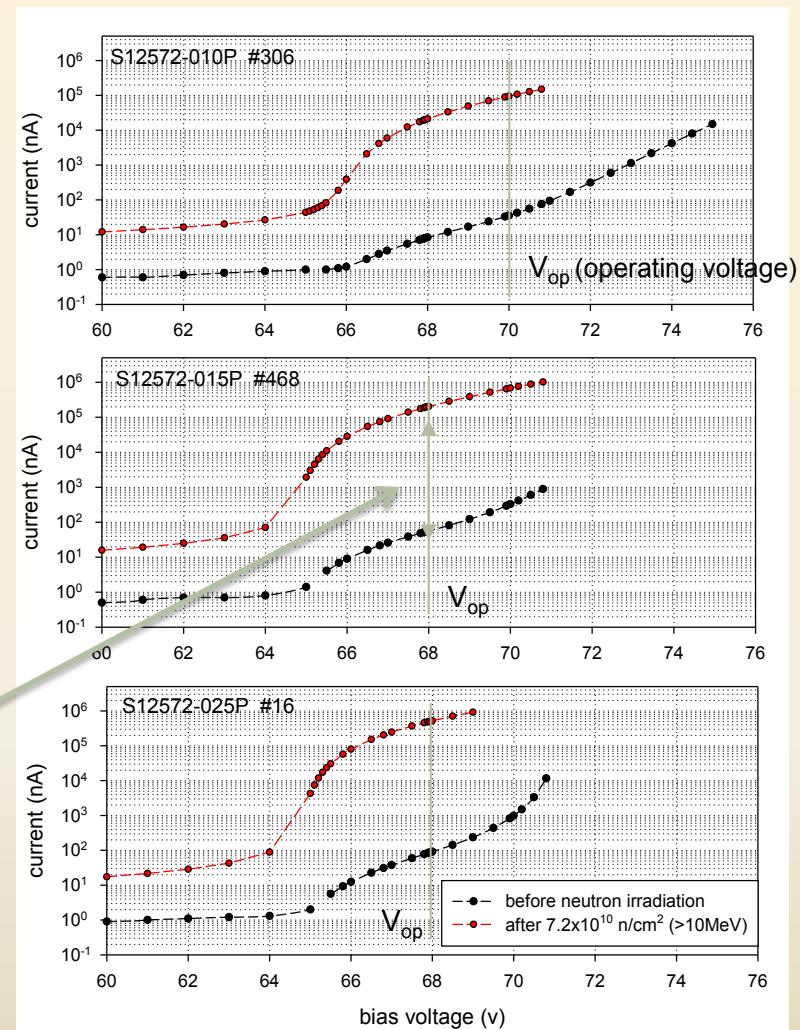
Radiation Effect

- Displacement damage due to neutrons- Increased leakage current
- Study the effects of neutron damage at:
 - LANSCE (LANL)
 - LENS (Indiana Univ.)
 - PHENIX IR
 - BNL Instrumentation



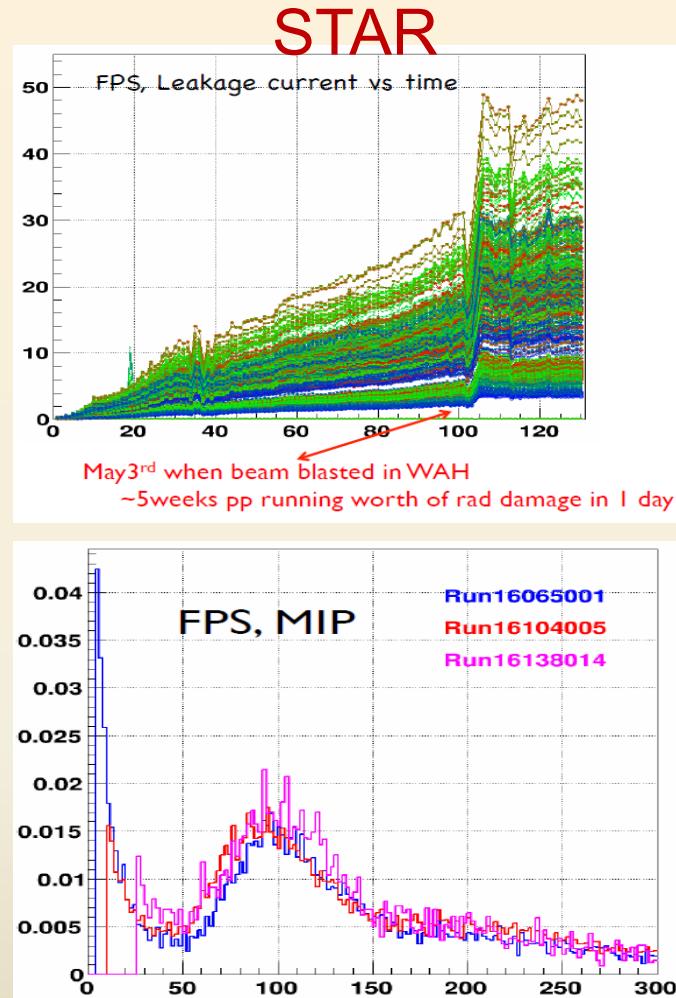
Dark Current vs Bias Voltage

- Measurements taken at LANSCE (Dec 2014)
- 3 pixel sizes: $10\mu\text{m}$, $15\mu\text{m}$ and $25\mu\text{m}$
- Measure dark current before and after irradiation
 - Integrated flux: $7.2 \times 10^{10} \text{ n/cm}^2 (\text{E} > 10\text{MeV})$
 - Corresponds to ~ 3 years sPHENIX running.
 - For $15\mu\text{m}^2$ pixel device, current increase from 50nA to $200\mu\text{A}$



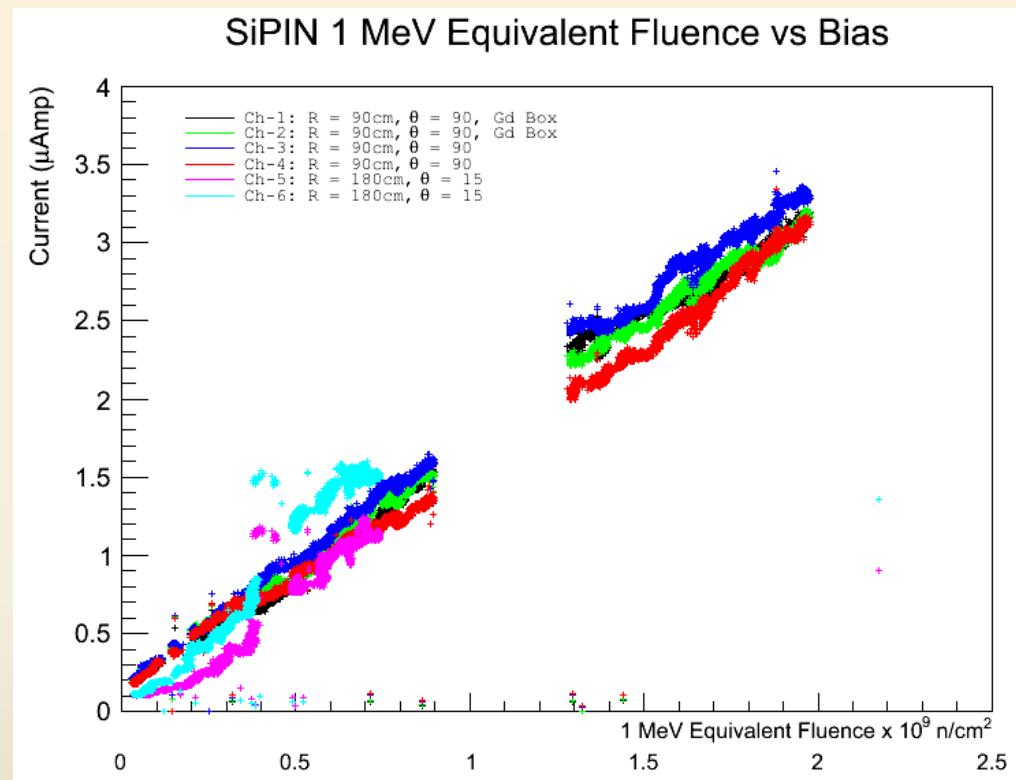
Leakage Current and Signal Response

- Increasing leakage current
 - Broader pedestal
 - Reduced signal-to-noise
- STAR measurements:
RUN15
 - FMS Upgraded to use SiPMs
 - Observed leakage current increase as a function of time
 - Look at MIP response as a function of time
 - No observable shift in MIP peak

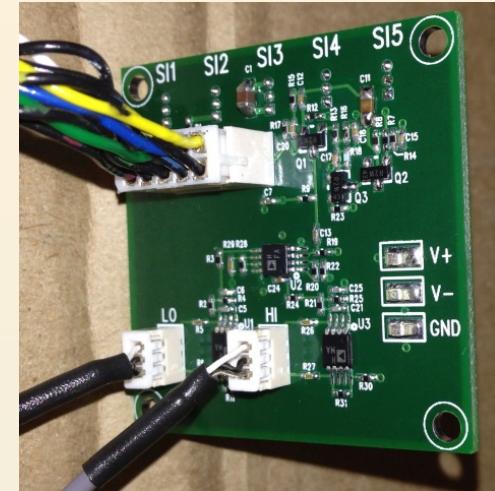
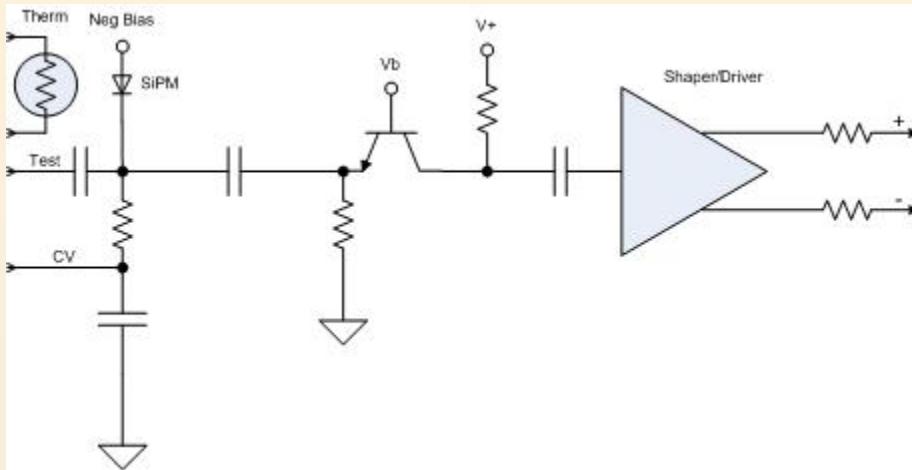


PHENIX IR Measurements

- 6 SiPMs ($25\mu\text{m}^2$ devices)
- Devices located at 2 locations:
 - 90cm from IP at $\Theta = 90^\circ$
 - 180cm from IP at $\Theta = 15^\circ$
- Measure current at fixed voltage May/June 2015
- Use CERN RadFETs to measure 1MeV neutron equivalent fluence
- We expect few 10^{10} neutrons/cm 2 per run

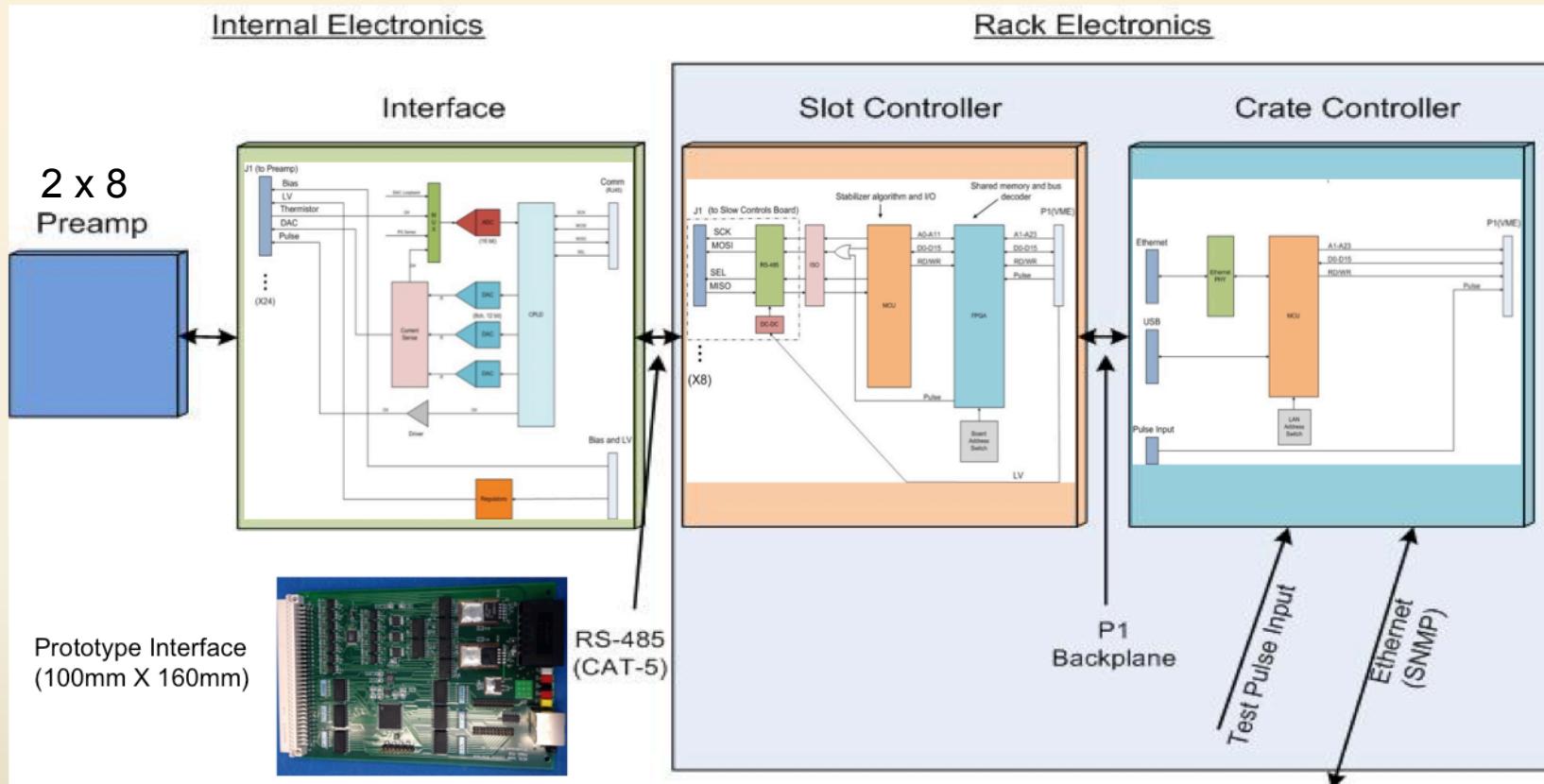


Preamp Circuit



- Local thermistor for temp monitoring.
- Control voltage input for trimming bias +/- 2.5V.
- Charge injector for signal test.
- Differential multiple-feedback filter/driver with 30nS peaking time for 65MHz ADC sampling.
- P_D :
 - CBA ~ 80mW
 - Buffer/Amp ~ 50mW
 - Shaper/ Driver ~ 120mW
 - P_{tot} ~ 250mW

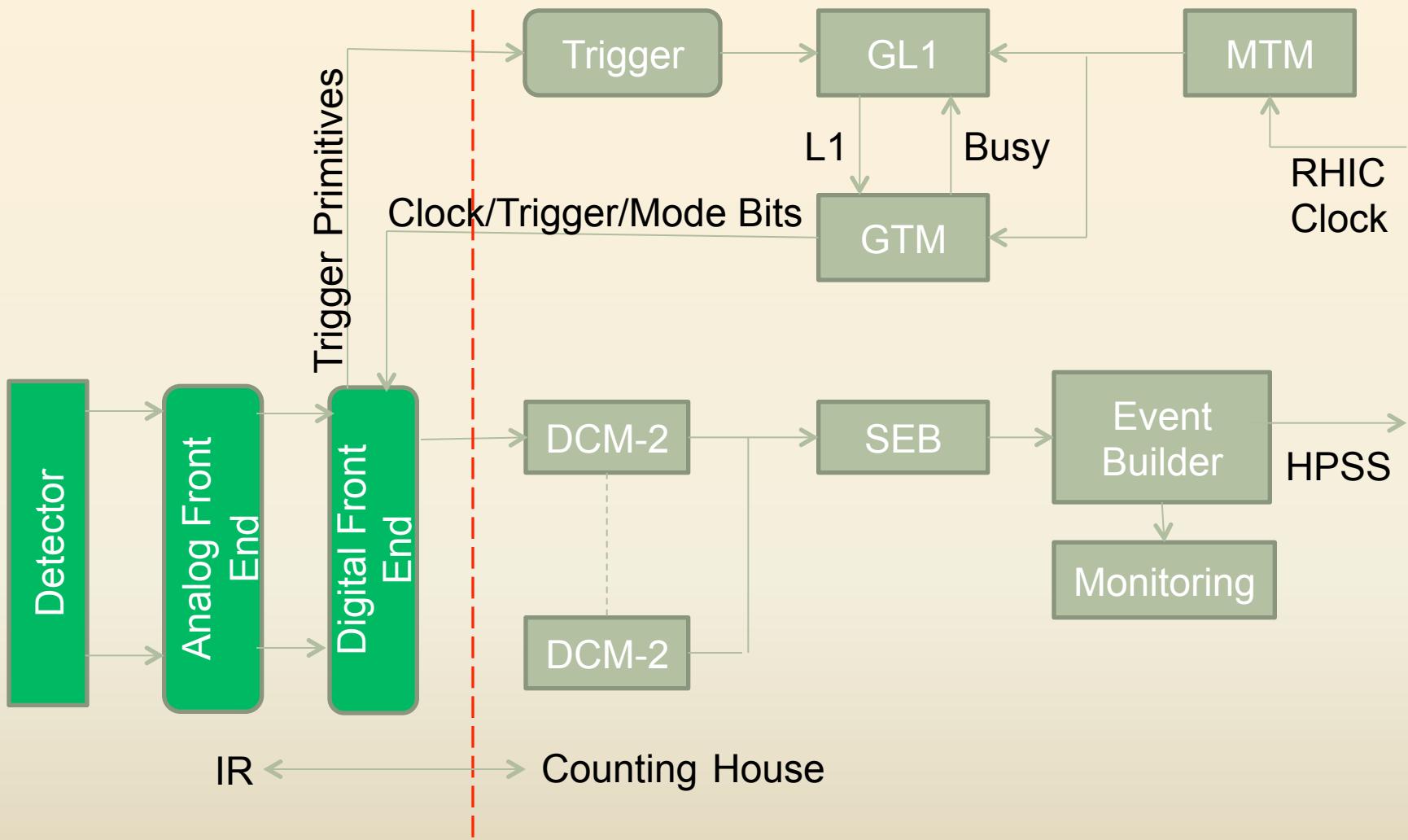
Front End Electronics Overview



sPHENIX DAQ Concept

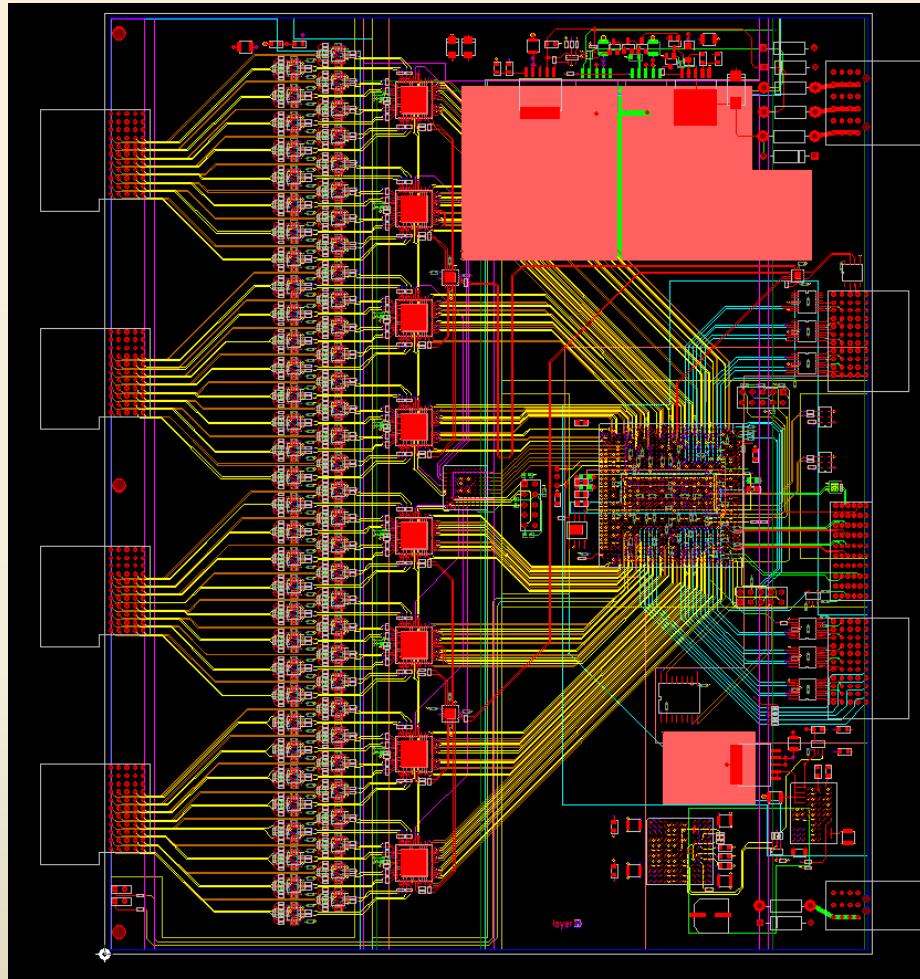
- Waveform digitization
 - Located near detector
 - 65MHz digitization rate
 - 14 Bit ADC
 - Form local trigger primitives for Level-1 trigger
 - Identical for EMCal and HCal.
- Take advantage of PHENIX hardware
 - DCM-IIIs: High speed readout, ~15KHz
 - PHENIX Event Builder
 - PHENIX Timing System (MTM/GTM/GL1)

DAQ Overview

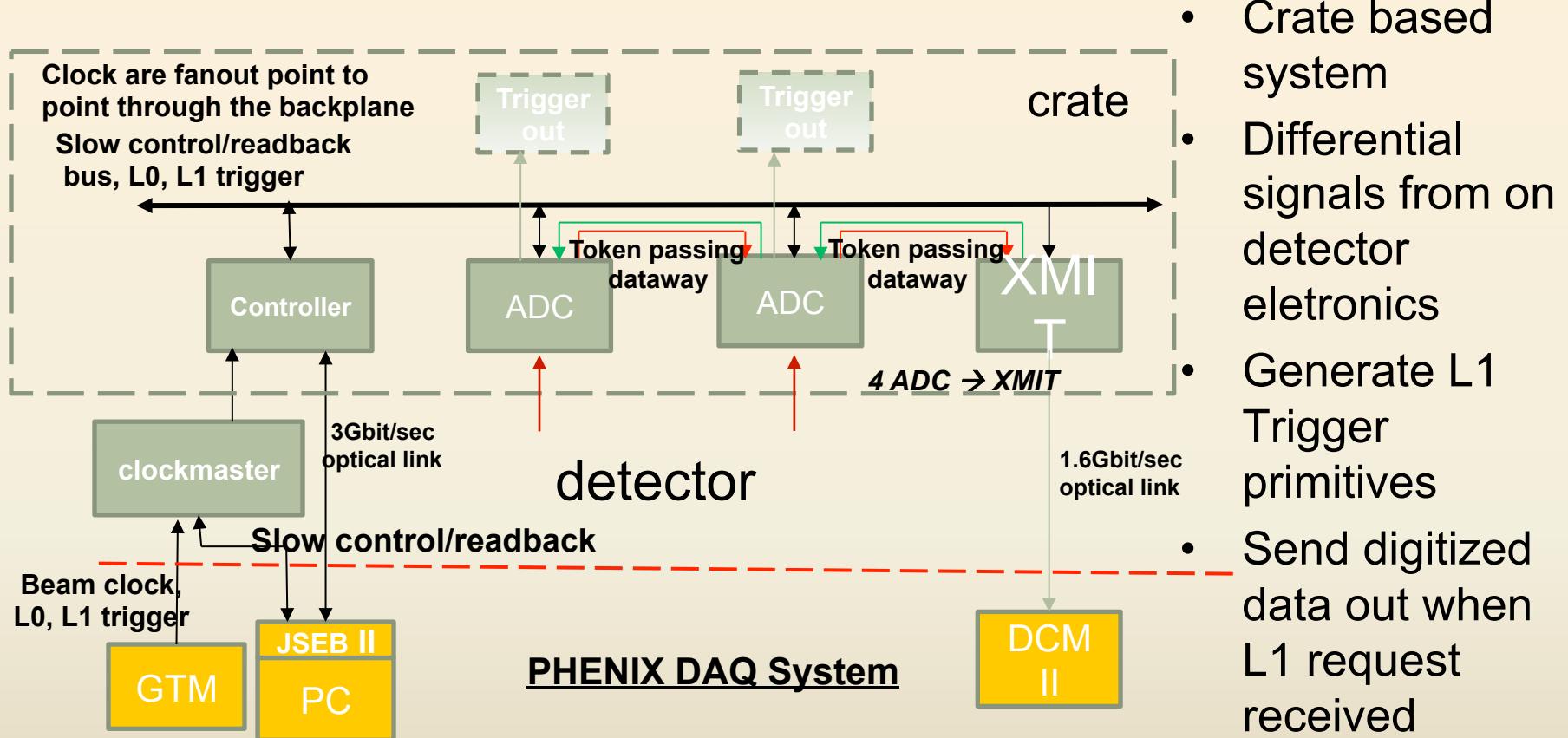


Digitizer System

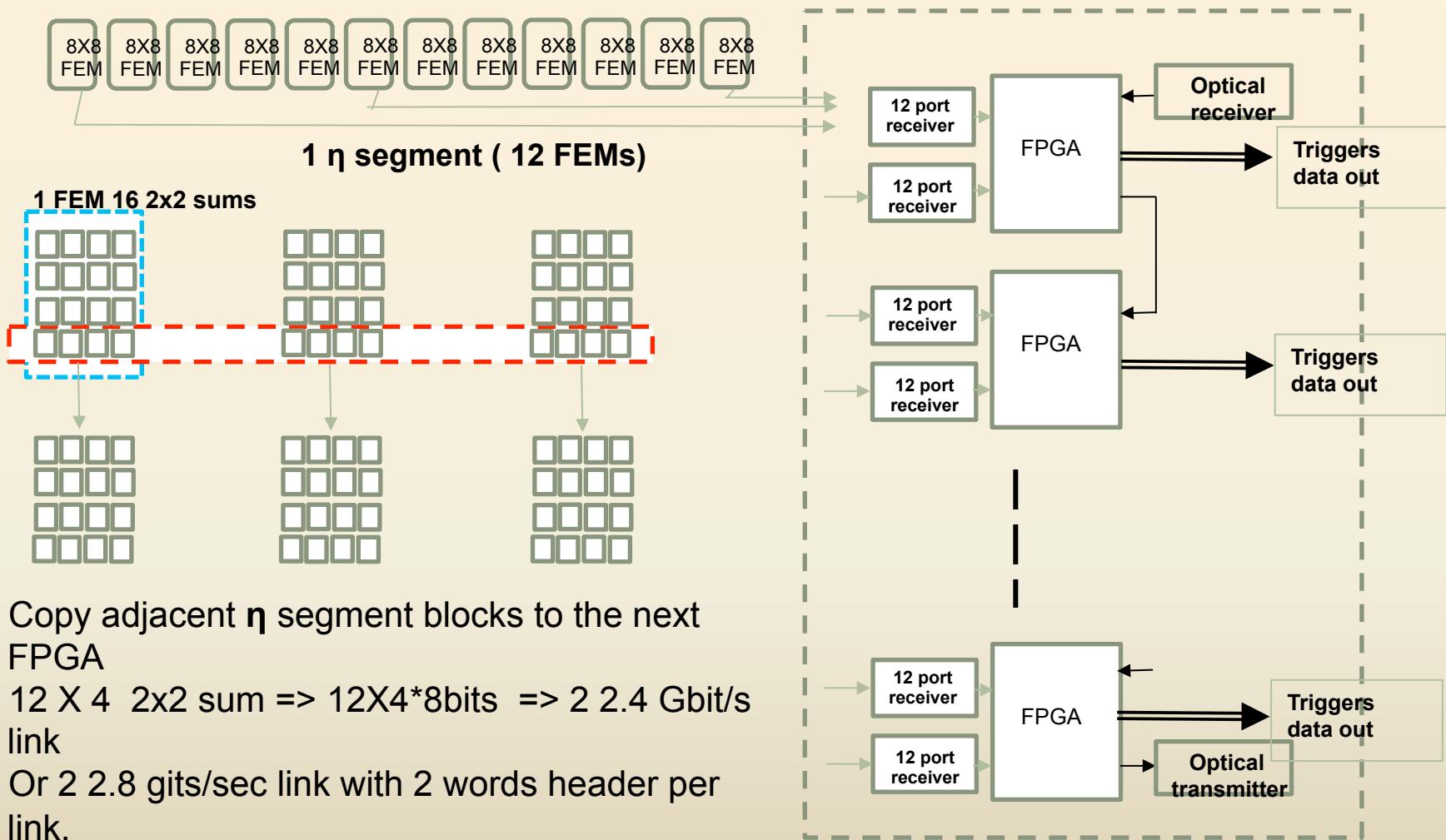
- Based on PHENIX HBD design
- 14 Bit ADC @ 65 MHz
- 64 channels per board
- Trigger Primitives based on 2x2 tower geometry
- First R&D prototypes are in fab with testing fall of 2015
- Should be available for 2016 beam test



sPHENIX Digitizer System

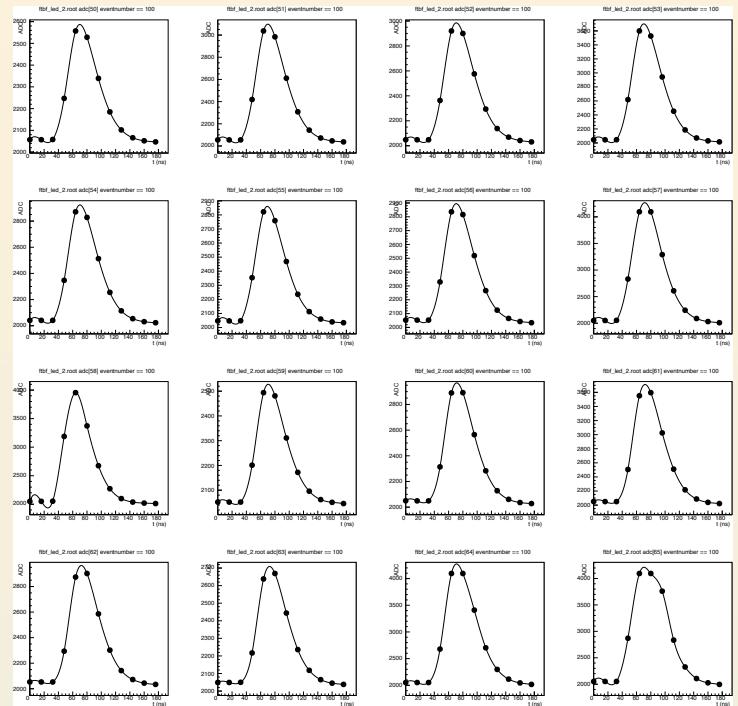


EMCal Trigger



Calibration and Monitoring

- Preamplifiers have built in charge injection.
 - System testing and monitoring
 - Electronics calibration
- LED Pulsar system system built into preamp boards
 - Pulsed through slow control system
 - Illumination of light guides
 - Experience in PHENIX: MPC, ZDC...
- Gain compensation by controlling SiPM overvoltage (Temperature stabilization circuit)
- Ultimate calibration offline using π^0 peak PHENIX EMCal



LED signal observed in
EMCal test beam prototype
Using HBD readout electronics

Issues and Concerns

- The electronics (WBS 1.7) had internal review in March 2017 and recommendations are being addressed
- Reference sensor is the SiPM
 - Temperature dependence
 - Radiation effects
- R&D work is in progress to design and test a common base amplifier for the upcoming beam test.
 - Gain scale
 - Signal-to-Noise
- R&D work is in progress for the next generation digitizers
- Reference design for trigger system is being developed based on 2x2 tower sums.
- Calibration and monitoring systems being developed.
- System integration and assembly